PAFI Phase 1 Test Program

Photos and Description of

PAFI Phase 1 Testing Program

FAA Technical Center Testing Program

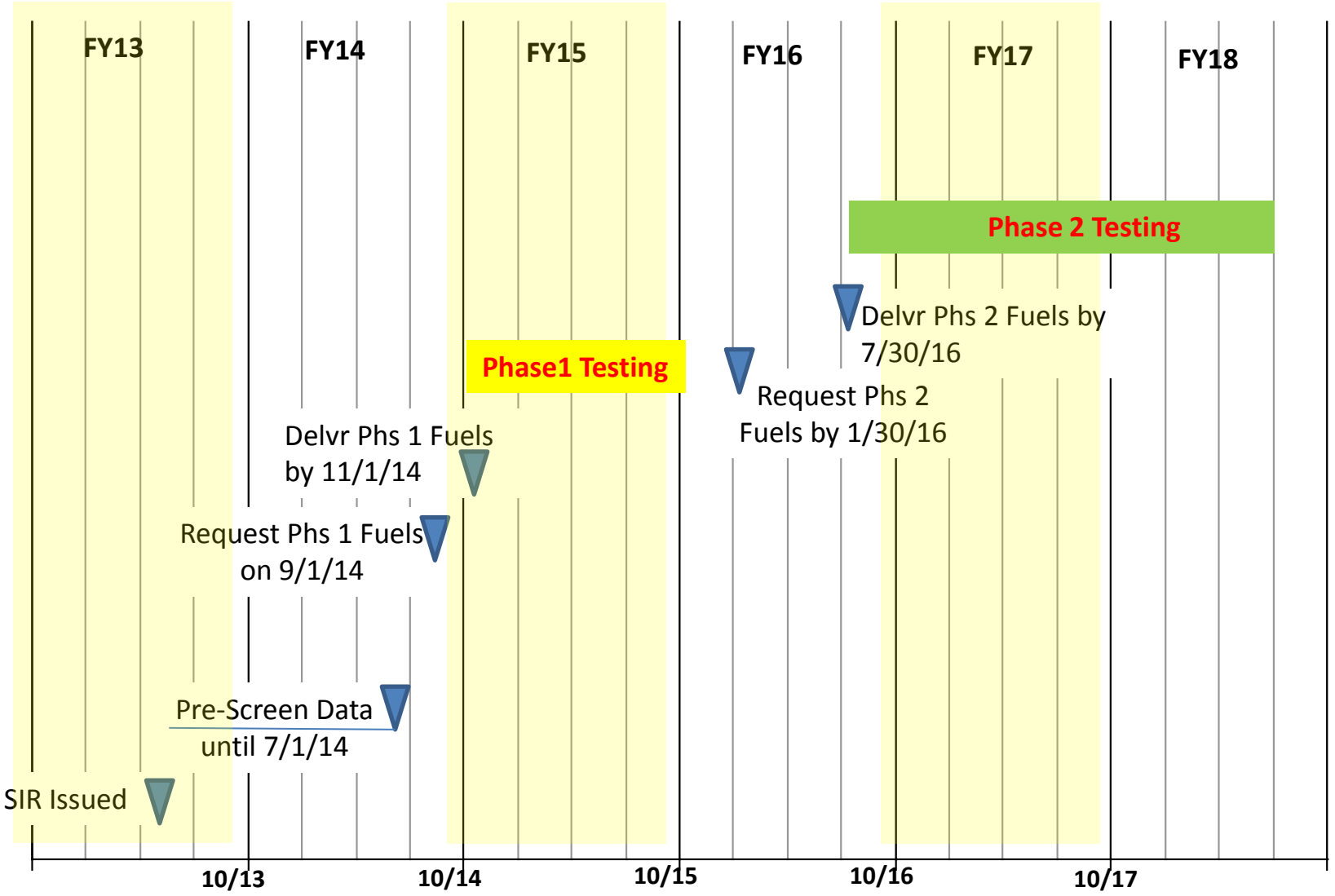
- Phase 1 - Evaluate candidate fuels via lab and rig testing
  - Chemical makeup
  - Performance properties
  - Establish credible and peer-reviewed test protocols for ascertaining necessary fit-for-purpose data
  - Baseline engine testing
    - 2 detonation points, rated power, combustion pressure profile, emissions
  - Fit for purpose testing across the ranges allowed by the fuel formulations (worse case formulations)
  - Ecological/toxicological assessment

- Phase 1 testing is currently in-process and on schedule for completion in accordance with the program schedule

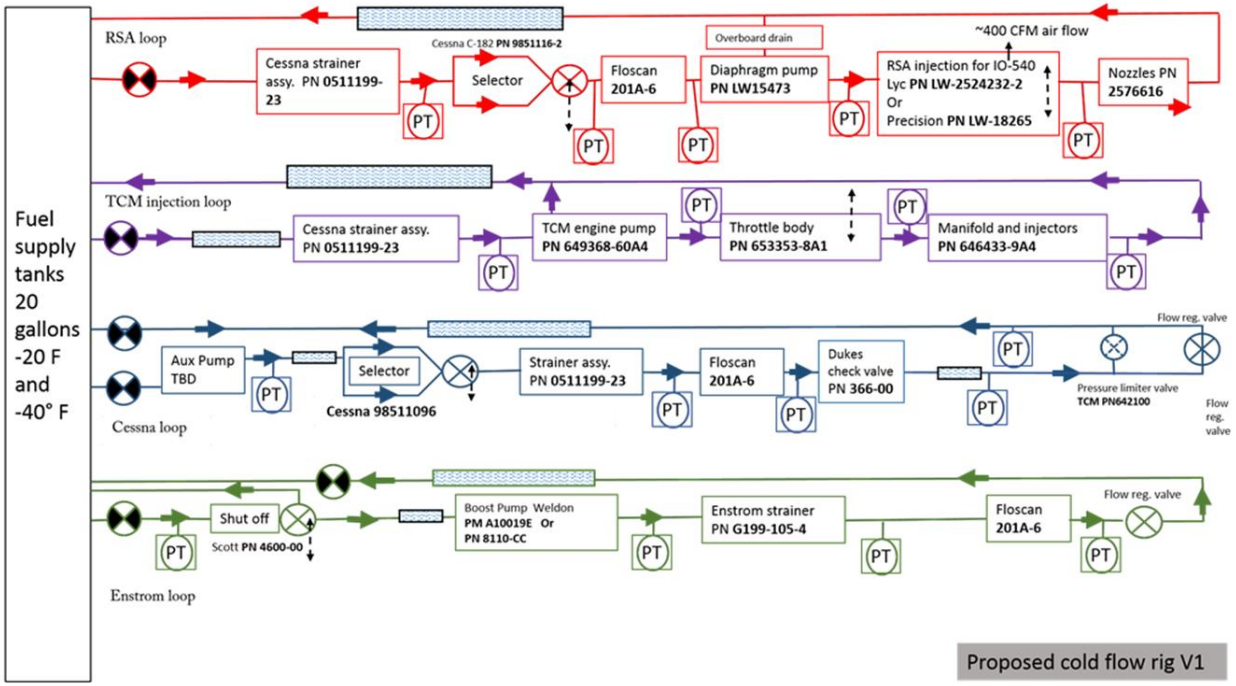
PAFI Phase 1 Test Program

- Phase 1 testing was initiated at the Tech Center in early 2015. Scheduled to complete in 4th quarter 2015
- Phase 1 test program consists of…
  - ✓ Laboratory Testing – traditional performance properties, and others
  - ✓ Materials Compatibility Testing – metallics, non-metallics, engine/A-C/distribution
  - ✓ Brief engine run – performance, detonation, emissions, starting
  - ✓ Environmental and Toxicology research and report
  - ✓ Fit-for-Purpose Rig Testing
    - Rig #1, Low Temperature Flowability
    - Rig #2, Carburetor Icing
    - Rig #3, Dynamic Fuel System
    - Rig #4, Storage Stability
    - Rig #5, Cold Storage
    - Rig #6, Hot Surface Ignition

Overall PAFI Schedule



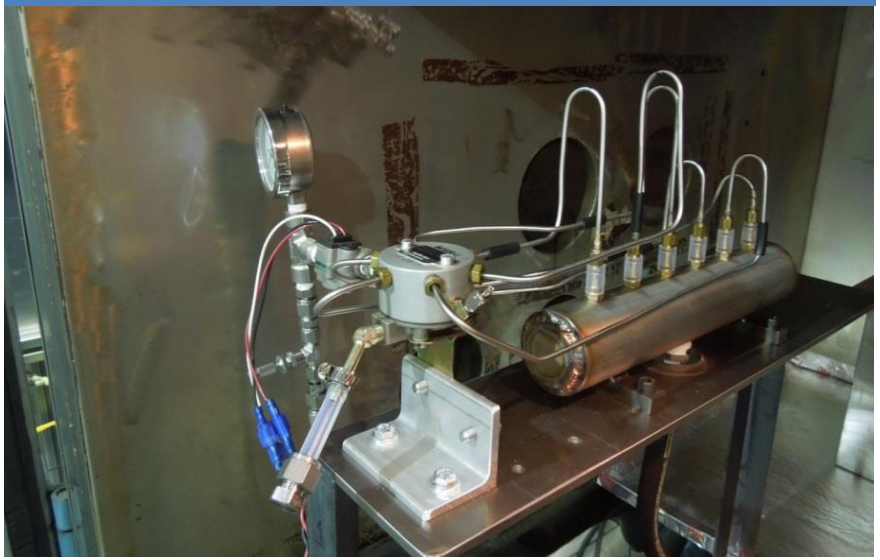
Rig #1 – Low Temp Flowability



Schematic of the various loops in the Low Temp Flowability rig, which evaluates the performance changes in hardware due to cooling of the fuel.

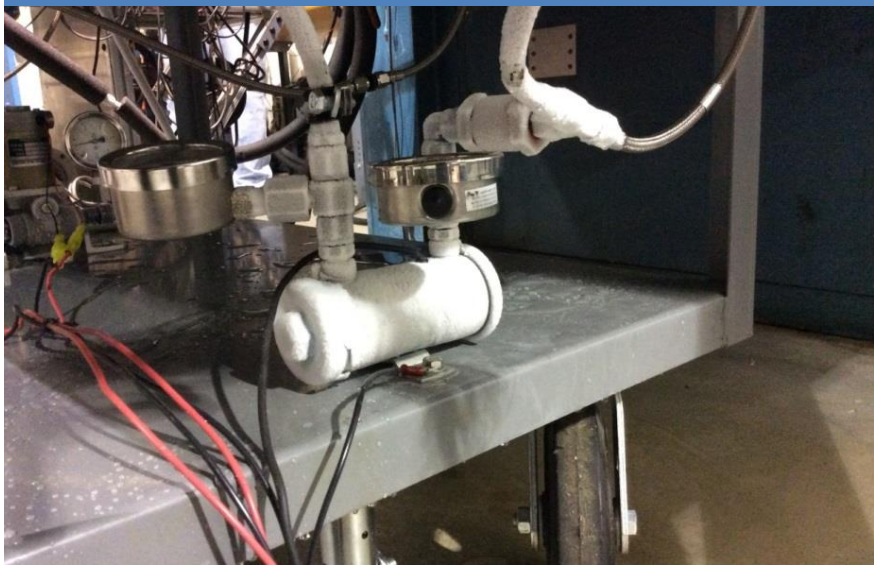
- 40° C test photos, showing hardware set up in freezer unit

Continental style fuel injection distribution system on cold test rig



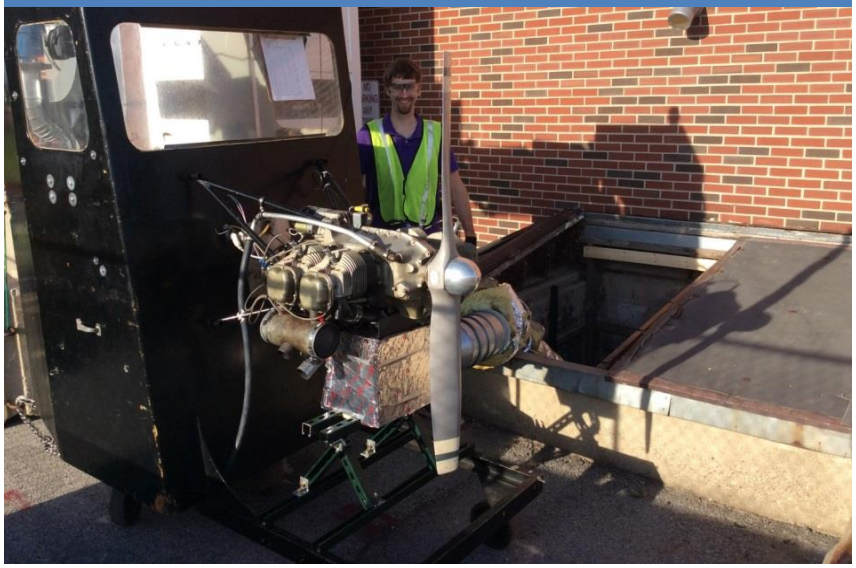
Continental and RSA style fuel injection systems in cold environmental chamber for pre test check out; -20C, -40C, and -58C (using Liquid Nitrogen cooling)

Intermittent duty fuel boost pump



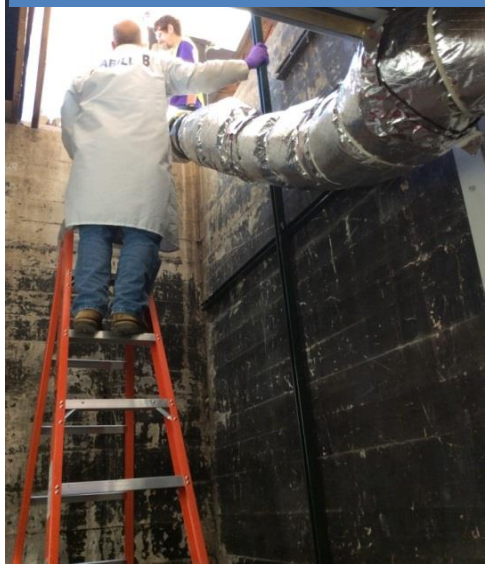
Rig #1 – Low Temp Flowability

Purdue Carburetor Icing Test Rig Engine Setup: Conditioned air duct shown entering insulated carburetor box



Conditioned inlet air and insulated carburetor air box

Conditioned inlet air ducting

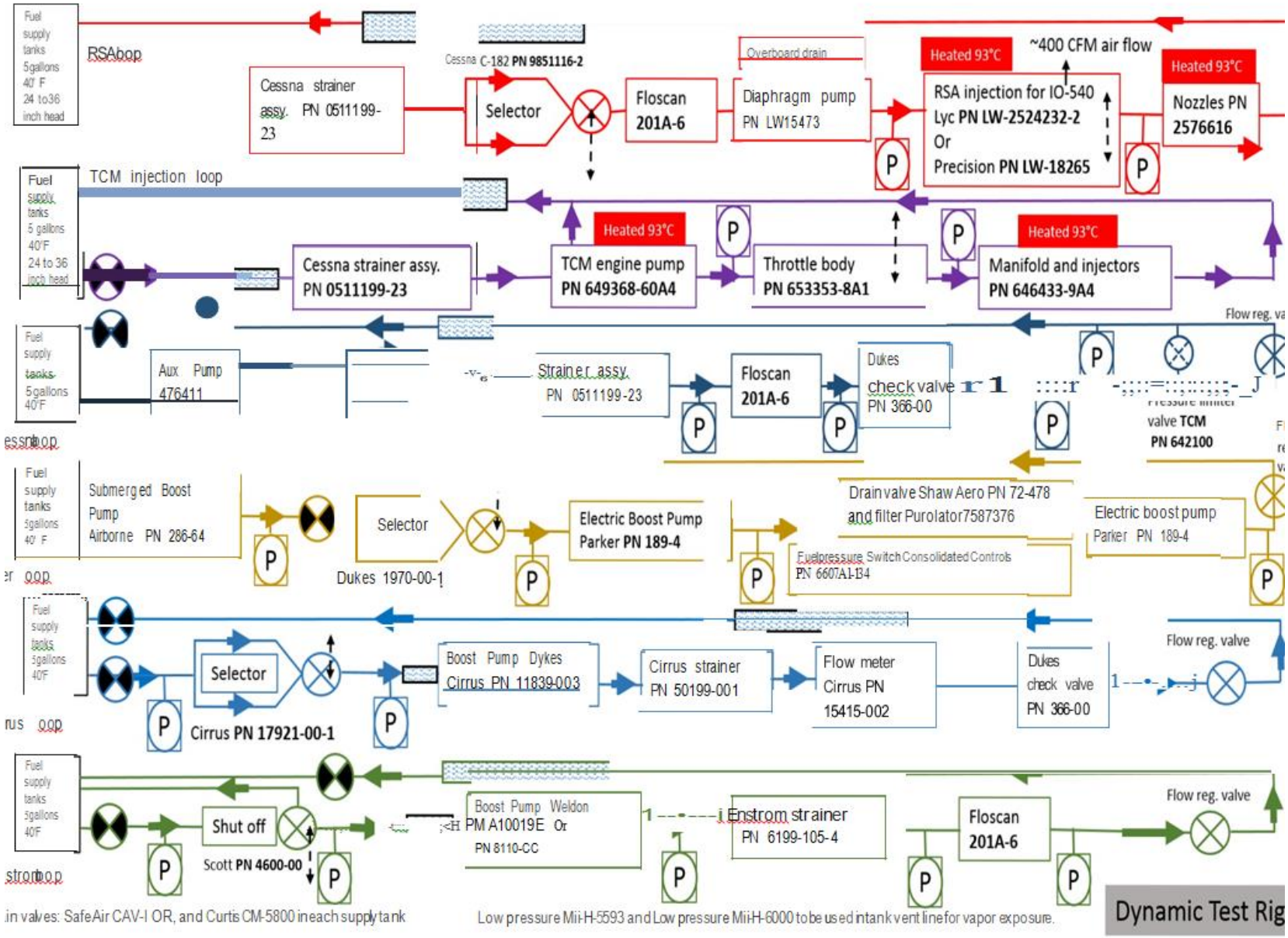


Air conditioning unit for Carburetor icing Rig

Another view of the conditioned air duct shown entering insulated carburetor air box

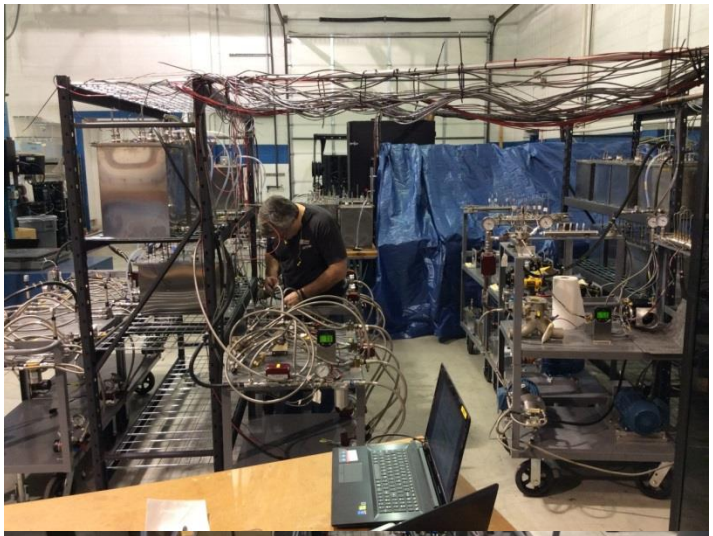
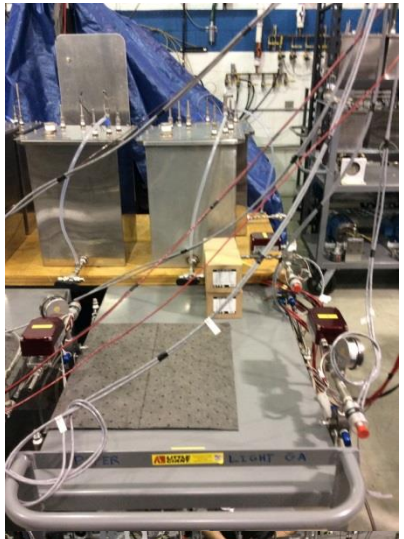
Rig #2 - Carburetor Icing Testing

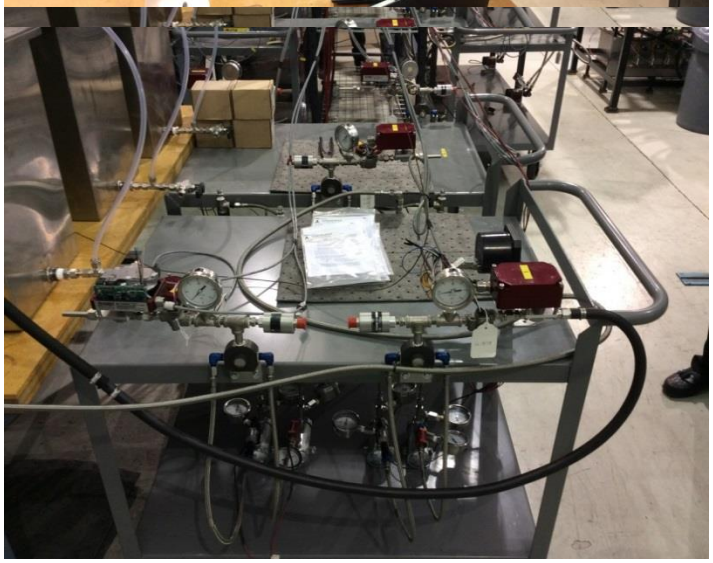
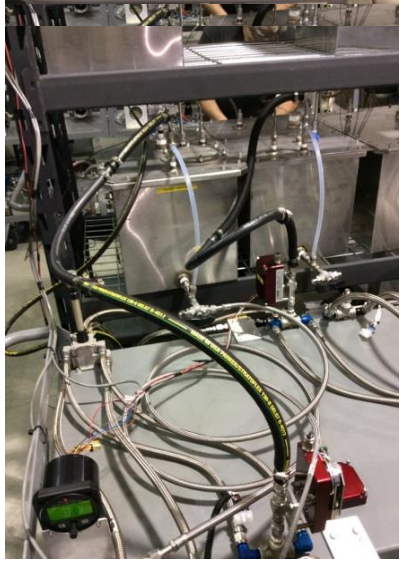
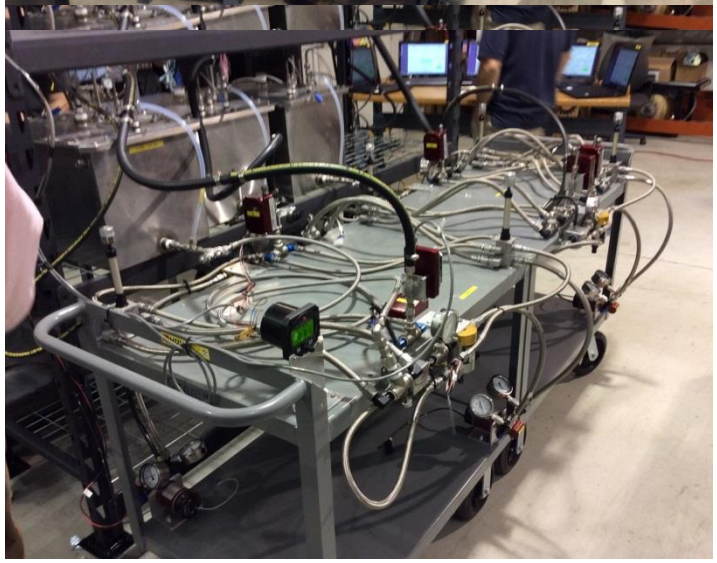
Carburetor Icing Test Rig, which evaluates the fuels potential effects upon carburetor icing.



Rig #3 – Dynamic Fuel System

Schematic showing the various loops in the Dynamic Fuel system rig, which evaluates the durability changes in the hardware following longer term flow testing.

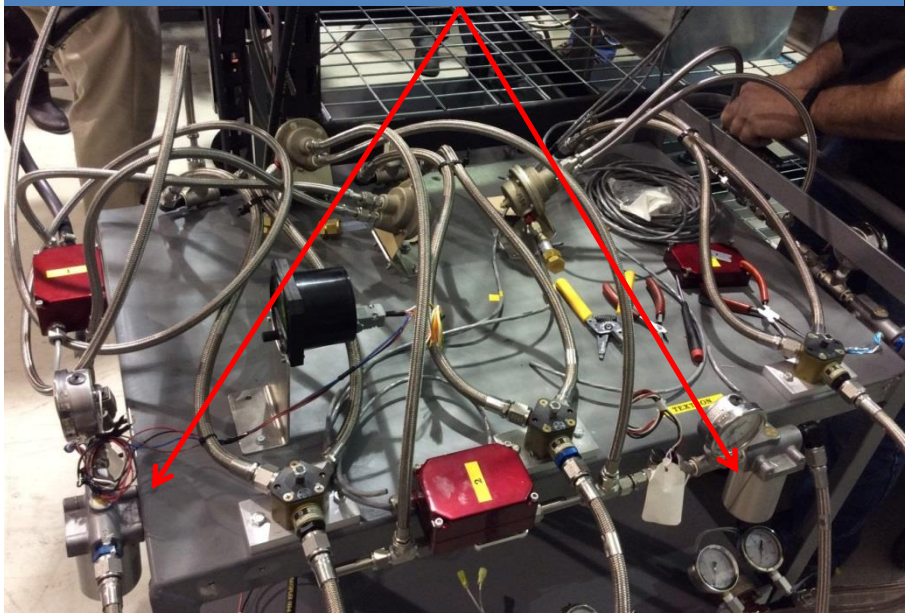



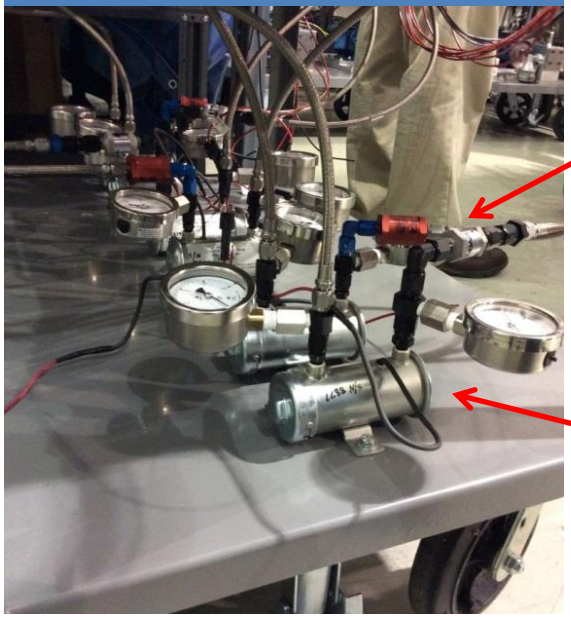
Rig #3 – Dynamic Fuel System

Extensive hardware involved in Dynamic Fuel System testing: 5 loops evaluated for 5 fuels (4 test fuels and 100LL baseline)

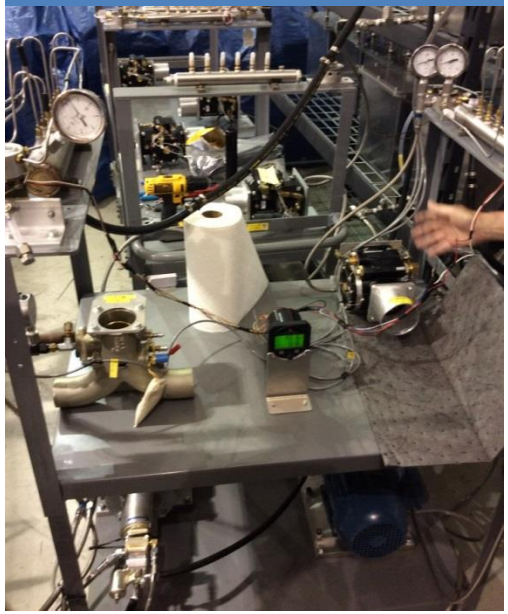
Gascolator: Used as a fuel filter and sump



Fuel pumps and fuel check valves

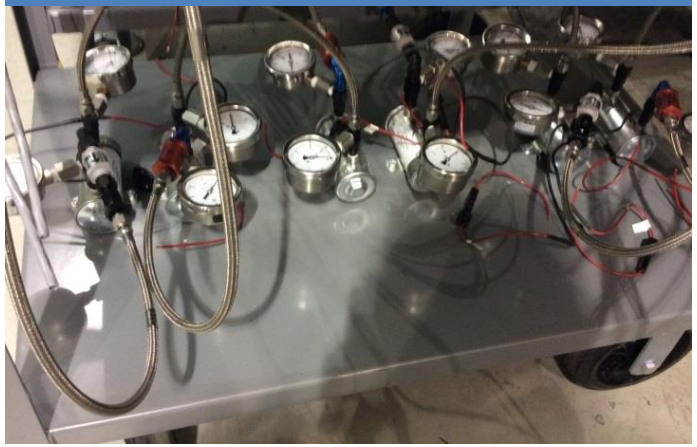


Throttle bodies



Fuel injectors

Fuel pumps and check valves



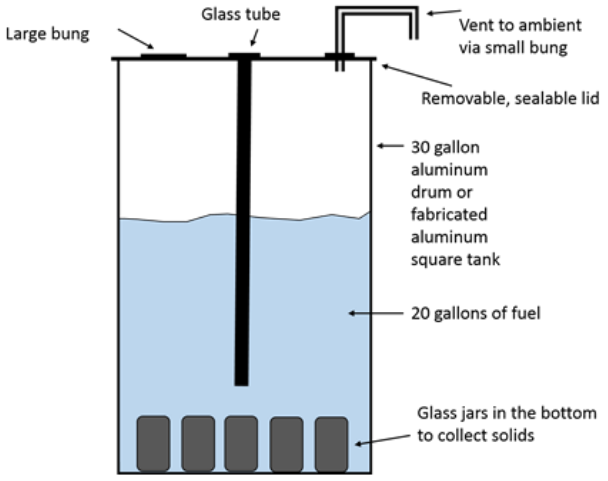
Rig #3 - Dynamic Fuel System

Representative hardware setup

Oven testing sample container, with 5 fuels ready for oven testing

Oven testing

FIT storage stability evaluation setup



Samples undergoing storage stability testing at FIT

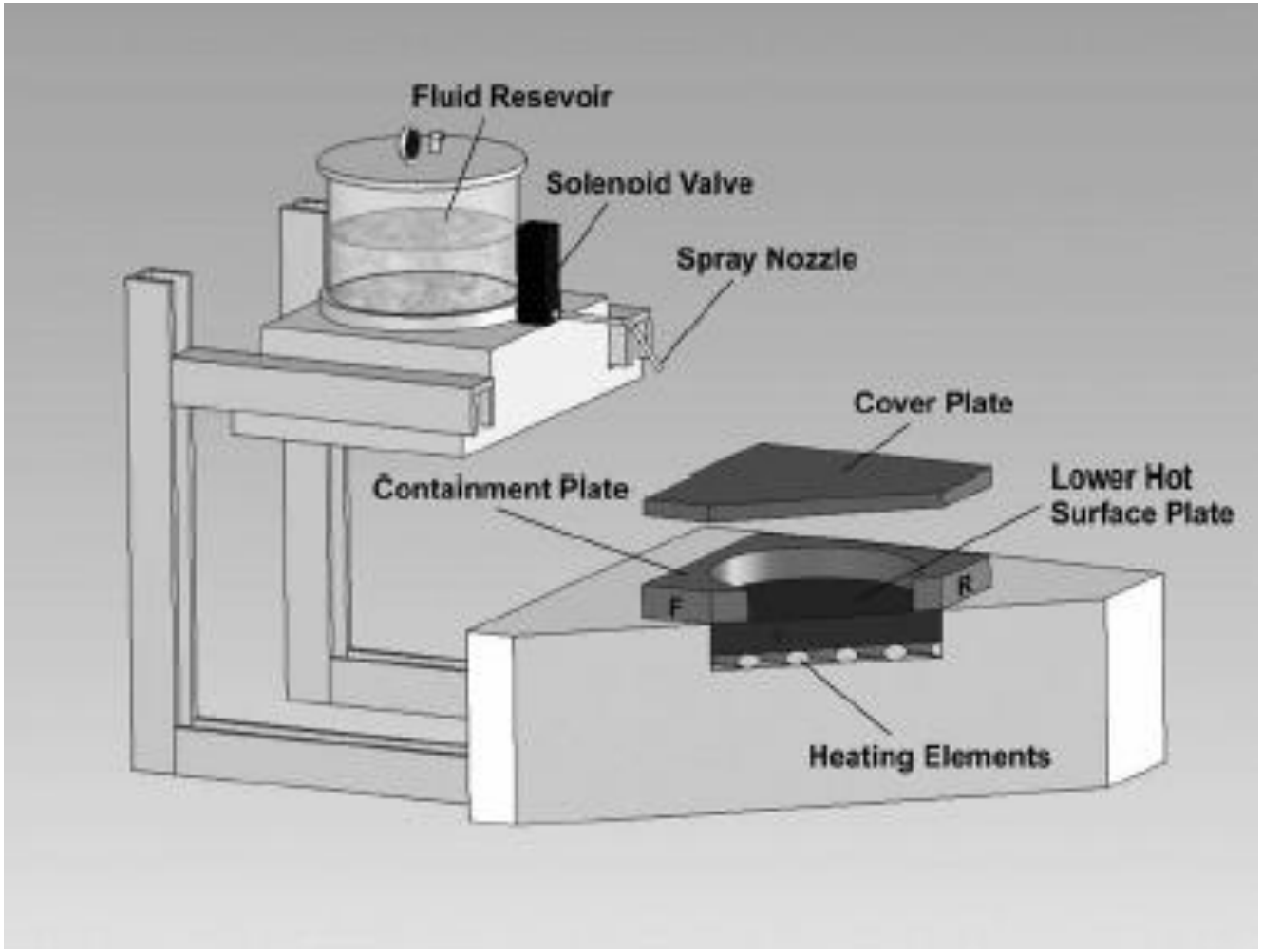
Rig #4 – Storage Stability

Storage Stability Rig, which evaluates the changes in fuel character when the fuel is stored at elevated temperatures.

Rig #5 – Cold Storage

Cold Storage Rig, which evaluates any propensity for phase or chemical separations with temperature.

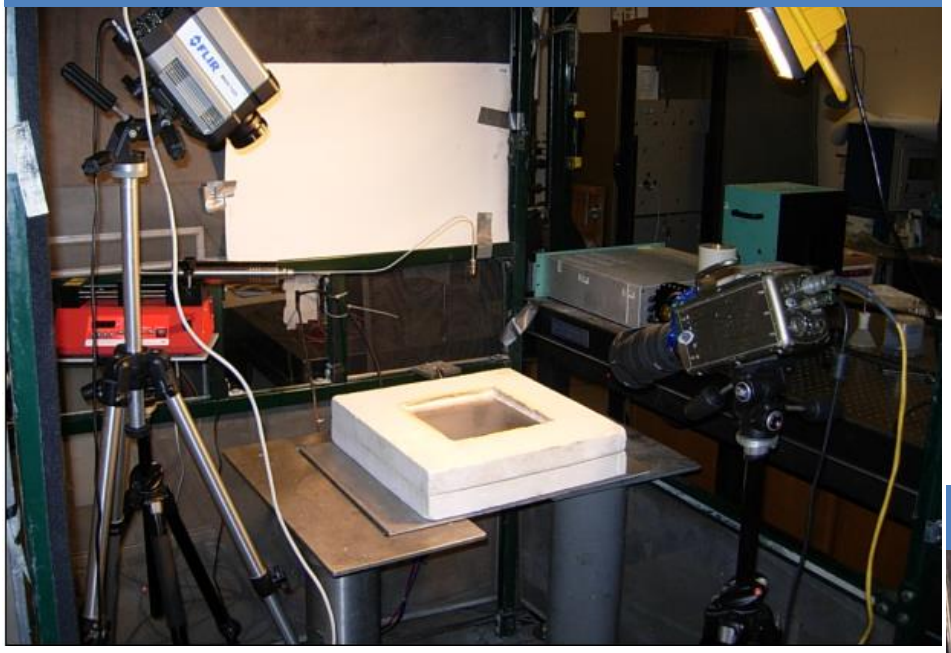
Freezer with -70^{o}C capability for Cold Storage testing



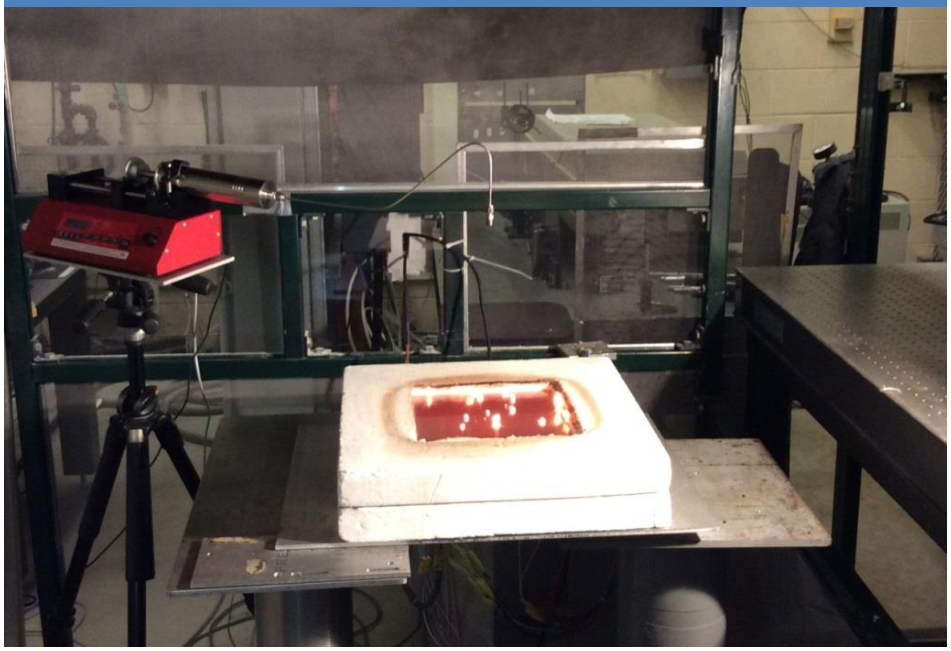
Rig #6 – Hot Surface Ignition Rig

Schematic showing concept of Hot Surface Ignition Rig, which evaluates any propensity for fuels to leave a residue when dripped on a hot surface such as the engine manifold during shut down.

Test instrumentation/rig setup



Testing in action, after 1 drop hit the heated plate



Rig #6 – Hot Surface Ignition Rig

Materials Compatibility Testing

Photo showing bladder material setup. Bladder and port are in fixture containing fuel – talcum powder is on bladder to aid in any leak identification

Multiple bladder/fuel setups undergoing testing

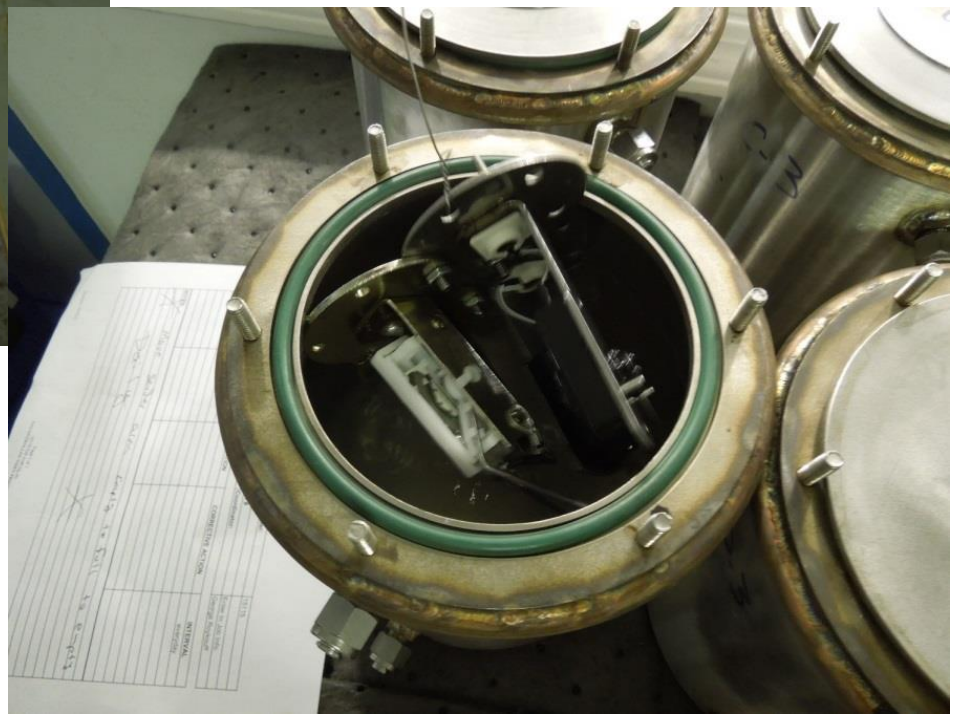
Distribution system fuel lines, filled and capped with test fuels, covered in talcum powder

Materials Compatibility Testing

Environmental oven for 93°C and 71°C soak test samples of aircraft metal and non-metal materials soaked in each of the candidate fuels for 28 days. In all, over 1500 individual samples.

Samples shown with vented secondary containment drums for oven tests. Yes, the ASTM method specifically calls out canning jars!

Materials Compatibility Testing

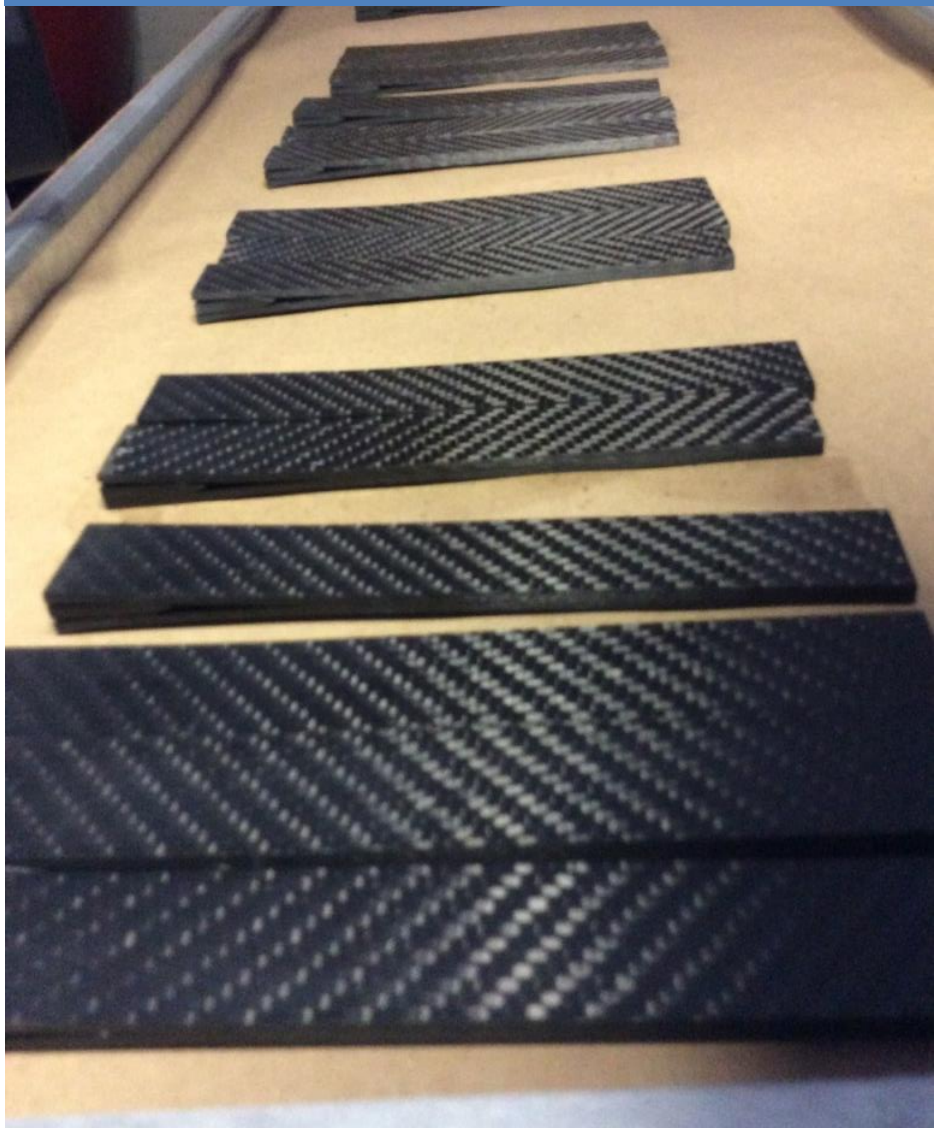


Materials Compatibility Testing

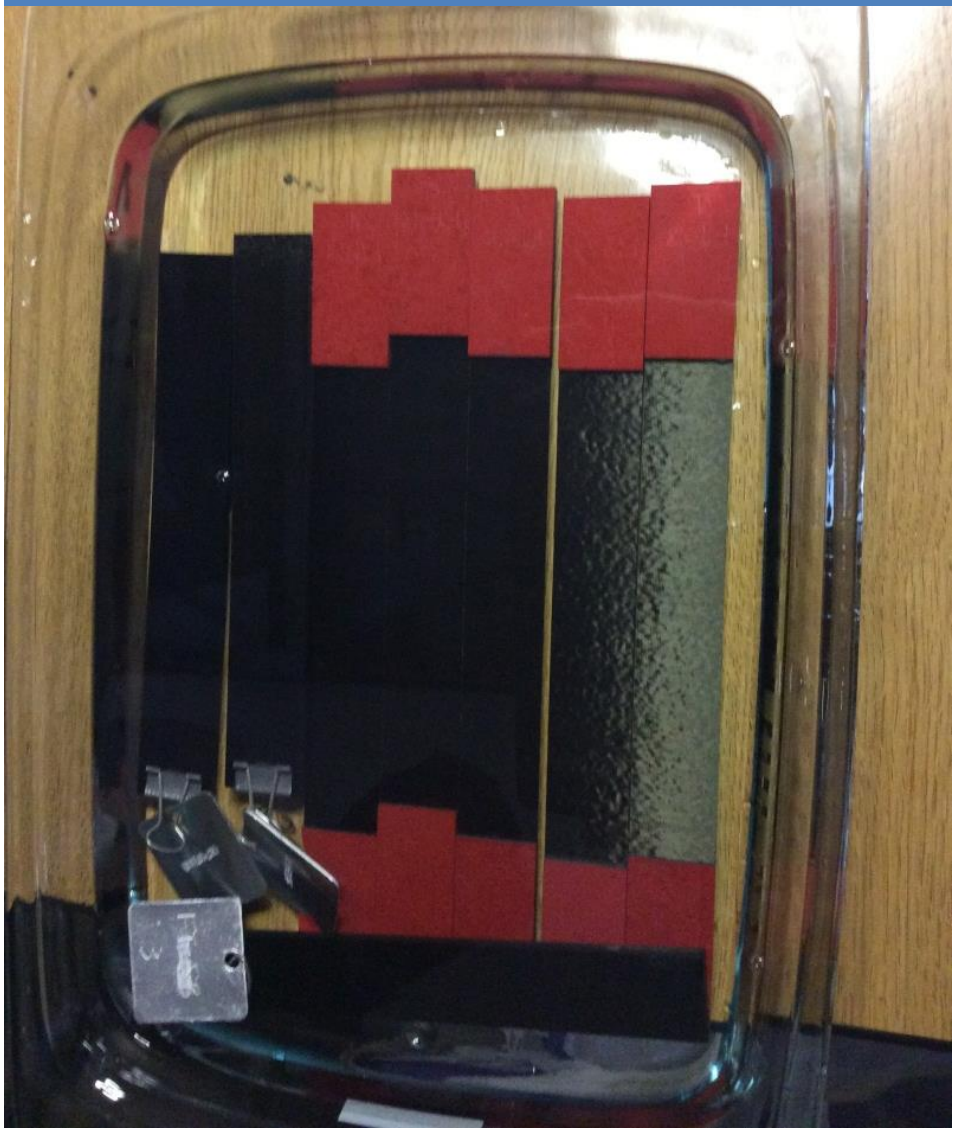
Float style fuel senders in immersion tanks

Soaked for 700 hours, exercised full range twice a day, checked for resistive output, pre and post test

Composite materials setup for wedge testing



Composite materials being “wedge tested” in fuel container



Materials Compatibility Testing

Composite materials being “wedge tested” in fuel container

Storage unit filled with multiple non-metallic samples undergoing materials compatibility testing

Drain valve testing setup

Close-up of drain valve assemblies ready for testing

Materials Compatibility Testing

Thread sealant testing

Distribution system filter used in materials compatibility evaluation

Materials Compatibility Testing

Engine Detonation, Performance, Emission, and Start Testing

Lycoming IO-540-K engine installed in the FAA WJHTC test facility for comparative detonation, performance, emissions , and start testing

Engine Emissions Testing

Lycoming IO-320-B1A engine installed at SWRI for emissions testing including particulate matter

Engine Emissions Testing

SWRI evaluation of emissions includes particulate measurement – which was not conducted at the FAA WJHTC

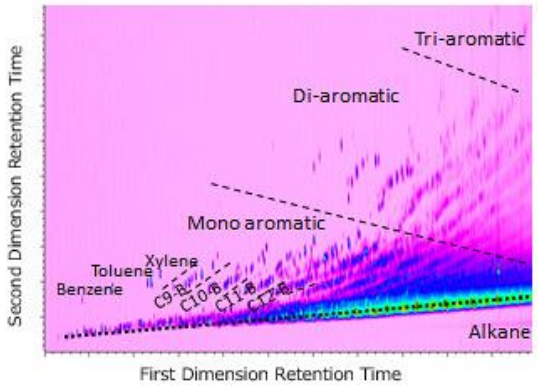
Environmental Toxicological Assessment

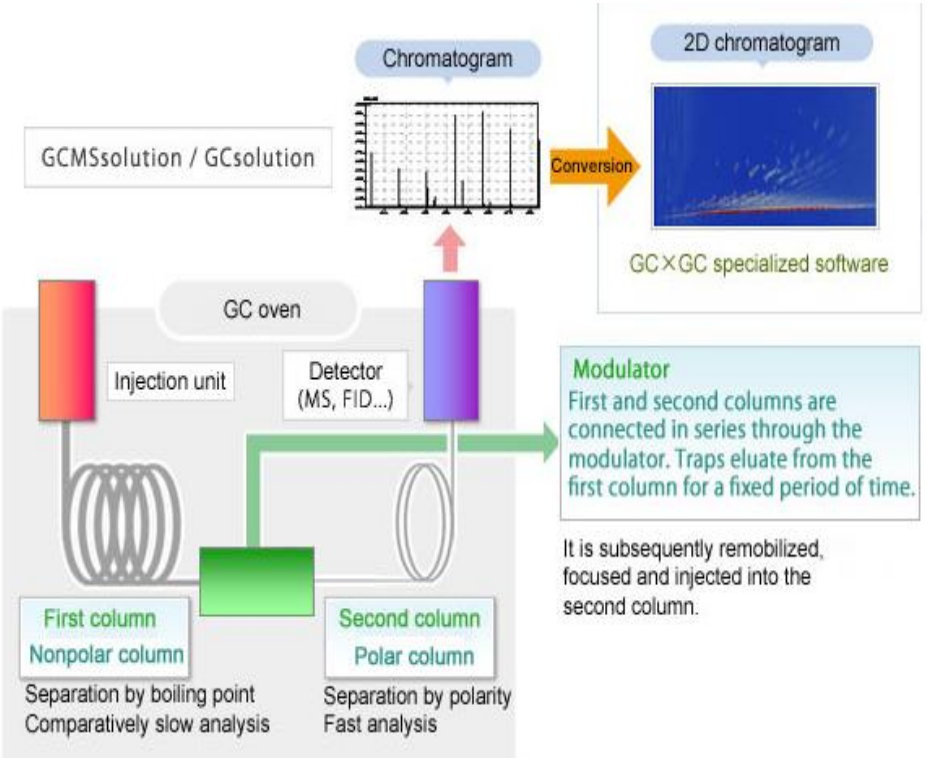
- Environmental/Toxicology Risk Assessment– An additional assessment identifying any issues in available literature and references for each of the formulation's major fuel components that differ from the community experience with 100LL, along with the experience regarding the use of the components in additional modal transportation fuels will be summarized in a final research paper.

GCxGC - Mass Spectrometer

- Evaluate and verify the exact chemical makeup of each candidate fuel
- Used to validate and establish baseline for all Phase I test results
- GCxGC testing is being performed in addition to the ASTM D6733 High Resolution GC, to evaluate the validity of the high resolution GC analysis

MDGC/GCMS Series





Pictures were accessed from SHIMADZU.com on 12/5/14.